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ABSTRACT

For more than 80 years, jobs in the United States have been designed by people for others. For most of these years, the experts in job design have placed the production technology above the job holder in importance. Since the 1950s, many jobs have been redesigned around new, computer-based technology. Often, the net effect has been to make those jobs more tedious or virtually to eliminate them. The socio-technical system (STS) approach to work design has evolved as a theory of understanding the complex interaction between technology and human organization, and as a method to improve technical effectiveness and quality of working life. It has done this by addressing both of these factors simultaneously as a means of pursuing organizational purpose and values. The management theory that results has been addressed to larger, more complex human systems. The work that results from the STS design methodology differs from the jobs of the past by creating roles as integral organs of a living system, not as parts of a well-engineered machine. Such a system has been in effect for more than five years at the Zilog, Inc., semiconductor plant. It has resulted in highly reduced turnover, increased production, and a high degree of worker satisfaction with the quality of working life. (KC)

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Socio-technical Systems Analysis and Manufacturing Technology: Addressing "Big Brother" and Computers in Blue-collar Work

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Socio-technical Systems Anslysis and Manufacturing Technology:
Addressing "Big Brother" and Computers in blue-collar Work

by James C. Taylor, Ph.D.

INTRODUCTION

For over eighty years jobs in the U.S. have been designed by people for others. For most of these years, the experts in job design have placed the production technology above the job holder in importance. Since the 1950's many jobs in the U.S. (white and blue collar) have been redesigned around new, computer-based technology. Often the net effect has been to make those jobs more tedious or to virtually eliminate them.

The socio-technical system (STS) approach to work design has evolved as a theory of understanding the complex interaction between technology and human organization, and as a method to improve technical effectiveness and quality of working life. It has done this by addressing both of these factors simultaneously as means of pursuing organizational purpose and values. The management theory that results has been addressed to larger more complex human systems. The work that results from the STS design methodology differ from the jobs of the past by creating roles as integral organs of a living system, not as parts of a well-engineered machine.

In the present paper I will describe recent organizational experience as affected by the values of job designers, the meaning of quality of working life, and the effects of a "systems consciousness" in manufacturing. I will also discuss these aspects and the end-results of organizational excellence and quality of working life.

JOB DESIGN

This brief history of job design divides the topic into three segments-the factory development, the Scientific Management development, and the Socio-technical Systems development. These three segments stretch along a time line beginning about 1790 and running to the present. The first two have often been referred to together as the "industrial era" (Bell, 1967). Factory development (1790-1900) characterizes job design during the English industrial revolution, and Scientific Management characterizes job design during the American industrial revolution (1900-1950). Socio-technical systems ideas of work design represent one highly visible manifestation of the "post-industrial" era.

Factory Management and Job Design. The English industrial revolution relied on the creation of tools and parts. The tools became the lowest common denominator. If a manufacturer wished to increase output he could make the tool larger, or he could employ more of the same tool. The replacement of human energy with first water power, then steam power followed the development of specialized tools and parts, and the division of labor among semiskilled employees. The factory concept would not have succeeded without the combination of specialized tools and the division of labor. Partitioning of production process was simply not an economic proposition unless there was a fair probability that the separately produced parts could be re-constituted to yield a workable version of the final product. Maudsley's slide rest, a simple innovation introduced in 1797, permitted lathe cutting of accurate

and repeatable screw threads from metal stock. From that point onwards there has been a continuous evolution in specialized tools, machines, jigs and fixtures to enable relatively unskilled labour to continuously replicate relatively skilled operations to a higher degree of standardization. The aim throughout the development of the factory system was to form the tools so that they fashion the work itself, and give to every part the interchangable qualities required for assembly. In other words, jobs were created to fit the tools required to create the interchangable parts of the manufactured assembly.

Scientific Management and Job Design. A useful counterpoint, and historical comparison, to the factory period of tools and parts, is Peter Drucker's 1959 observation that systematic study and/or attempts to improve jobs and work began only about 80 years ago with Scientific Management. According to Drucker, Scientific Management theorists established a history of technology with work, not things (e.g., tools or parts) as the focus. Until about 1905, he explains, "work had been taken for granted by everyone-as it is still apparently taken for granted by most students of technology" (p. 48). He continues that the Scientific Managers were radical for their time because they took the tools as given and studied how to make the best use of them. Thus, rather than simply giving workmen larger tools (e.g.,shovels) or merely adding more men with shovels to a job, Scientific Managers directed workmen to work more efficiently with the tools at hand based on studies of the workers' movements. This approach to job design has found its way into white collar and professional occupations, especially those employing women. But unfortunately Scientific Management has proved to be an incomplete paradigm for complex systems and turbulent environments. By 1950 the work designs of workers taking individual direction from their managers/supervisors (which resulted from that approach) were proving too cumbersome, rigid, and slow to adapt to changes in the consumer market, the labor market, and in technology itself.

Socio-technical Systems (STS) and Role Design. STS as an approach to viewing work system design emphasises the product of the work rather than either the work itself or the tools of production. The STS concept has evolved from the early 1950's when it was a process response to the introduction of new technology. Since that time, STS has become several things: 1) a sophisticated field of inquiry, 2) an analysis methodology suitable for understanding the essential nature of the work or purpose of an organizational system within its environmental context (Emery, Foster & Woollard, 1967; Englestad, 1970; Taylor, 1978), 3) a perspective suitable not only for the individual work group, but for the organization as a whole, and the macro-social level as well (Trist, 1981); and 4) a powerful, purpose-oriented approach to designing and redesigning work systems (Hill, 1971; Taylor, 1978; Davis, 1981). STS design differs from many other post industrial approaches to the problem of matching work to people by beginning with the institution as an open system engaged in transforming inputs to achieve desired outcomes in pursuit of a conscious purpose or mission.

STS design is a structured, teachable, participative method of designing organizations for a purpose. It is a combination of satisfying jobs, cooperative/coordinated social organization, and appropriate technology for effective performance based on designing for a stated purpose. This focus aids in creating a consciousness of the work system in which all members can identify with a system purpose or mission and its associated product or outcome, as opposed to member identification with either their work alone (what "they do"), or the machines/tools/or techniques they apply. The jobs that result are work roles which fit as necessary "organs" in a living organization. The intent here is to present STS as the mutual

influences of purposes, products, tasks, tools, and social organization, and to establish a view of choice in the design of jobs and work. This approach is based on the unique view of "technical system," which includes both the raw material (input) to be converted into the product (output), plus the "core technology" (i.e., tools, techniques, procedures, skills) which are required to provide the effective conversion of input to output.

STS originally developed in Indian weaving sheds, and British coal mines in the 1950's, and was further developed in Scandinavia in the manufacturing and continuous process industries during the 1960's and early '70's. Use of STS concepts also began in North America as early as the 1960's although the cases themselves were little publicized. The American experience concentrated on development of STS application methods in an expanding range of industries. During the 1970's STS became established as an effective way of improving white collar service and administrative units as well as blue collar settings. Most recently STS has been applied to professional organizations as well (Taylor, Gustavson & Carter, 1983). STS has thus become largely an applications tool--a proven method for improving systems effectiveness and quality of working life.

The Costs of Scientific Management. Around 1910, F.W. Taylor, and F. B. Gilbreth separately, provided the elements for Scientific Management, in which controlled observation and measurement led not only to combining labor requirements of the production line, but of scientifically planning the work load and skill level of each work station as well. Planning and measuring costs money, but until recently there seemed no other way to reduce the downtime losses inherent in the original factory system's fractionation of production. High costs are inherent in production based on fractionated tasks. The further one pushes fractionation the greater these costs become, because they are related to human responsiveness (Emery, 1977). Emergencies or crises cannot be determined or predicted or defined away. Control systems must be considered which can change the system, because, by themselves, assembly lines and computer programs can be too cumbersome to adapt without change. Industrial era assumptions have directed us to specialize that control in management or staff professionals-this is clumsy and expensive.

The almost complete correlation that once existed between higher levels of investment in production system equipment and processes, and the resulting higher levels of workers productivity, has begun to break down rapidly over the past two decades. The "scientific management" of technology, where people are paced, monitored, and their performance measured on jobs that take only a few minutes to perform has been the quintessence of this form. Many of the operations most advanced in the application of these traditional industrial concepts-automobile production, consumer electronics, banking and insurance transaction processing, for example-today are among those with the greatest problem in achieving productivity, quality and motivational results. They are not flexible, and unable to adapt to changes as they occur.

The rapidly increasing pressures for fundamental new work patterns require sweeping changes in conventional production concepts. The power of the mechanization and specialization techniques will have to be maintained; but they shall have to be subordinated to the recognition that people's skills and motivation, and the clarity and efficiency of information, are today as important to productivity and quality as the machines with which they work.

Technological Determinism. Scratch any piece of technology and you will find the values and aims of a society it was designed to serve. For technology is like genetic material-it carries with it the code of the society that conceived it. This is why technology "determines" skills, jobs, social relations, and organizational structures (Davis & Taylor, 1976). What are the values of technical systems designers, and how are those values shaped? In 1955 Davis and his collegues reported that industrial engineers valued the use of tools and the efficiencies of minimum training and simple repetitive jobs over the considerations of satisfaction with work requiring discretion and human adaptability. The shift in emphasis from tools to work noted by Drucker became, in the 50 years since 1900, focused not on humans as able to contribute to work process in their flexibility, but on their machine-like qualities. In effect Scientific Management became a way of treating people as replaceable parts in the work machine, and not as unique contributors to the work process (Boguslaw, 1965). Since the 1950's the environmental turbulence has increased, not diminished, and the demands on work systems to be flexible have increased exponentially. Despite this environmental pressure job designers (systems analysts as well as industrial engineers) were recently found to still emphasise machine-like efficiencies over any value of unique human contribution (Taylor, 1979a). Production engineers, engineering managers, systems analysts, and data processing managers were asked to list the five most important principles of job design. They identified maximizing operational cycles per unit time; efficient use of machine resources; making jobs as simple as possible; reducing manpower; and providing management with better information. The principles are those of the industrial era, and the designers tend to explain their use of them as a matter of following the directions of their firm's top management. Because today's managers continue to tacitly take these principles as guidance, design proposals for today's work systems are often based upon outmoded concepts. Because this bias is so pervasive and so little acknowledged, proposals that rest on other principles, such as STS, are viewed suspiciously.

Advantages of STS. The application of STS has, for 30 years, provided an accumulating body of evidence that organizational choice in technology and social systems has promoted effectiveness and employee well-being (Pasmore, et al, 1982). In particular the literature demonstrates the ability to incorporate social system choices into the design of effective organizations using the involvement of management, and employees (unions, too where possible) in STS-based efforts (Sullivan & Davis, 1980; Taylor, 1981). This demonstrates the potential for integrating the values of organizational members into the process or organizational design. It also points to another important question-what aspects of working life do organizational members consider important?

Under industrial era assumptions this question has been avoided in favor of the question: what characteristics should job holders possess in order to conform to the demands and requirements of the present technical system? In short, organizations sought out individuals whose skills and personality matched the fixed and unalterable characteristics of work. The fit between person and job could then be measured using standardized indices of job satisfaction. By the 1970's when employee absence and turnover rates had grown to an all-time high this dominant value resulted in surveys reporting the consistent and astounding statistic that over 80% of American workers were at least minimaily satisfied with their jobs (Taylor, 1976). This is in part a result of selection "fit" described above; together with an acceptance that when it comes to work, the technology counts more than the people. It reflects both the "deterministic" technology and the values and beliefs of western industrial society.

QUALITY OF WORKING LIFE

An alternative approach to the problem of incorporating human preferences into the design of organizational systems is offered by quality of working life (QWL) research. This approach consists of identifying those aspects of work that are seen as desirable by organizational members, and incorporating that information into initial design considerations. This potential has been recognized in the opportunity provided by evolving technology so rich in potential variations and arrangements that design decisions can depend almost exclusively on the social side of the situation (Davis & Taylor, 1976). In application, this requires that the construct of QWL be specific and concrete as defined by organizational members. In 1973 the first international conference on QWL was held in Harriman, N.Y., from which the definition of QWL was begun (Biderman & Drury, 1976; Davis & Cherns, 1975; Taylor, et al, 1973). Several systems and standard definitional frameworks of QWL resulted, but little progress toward a convergence on this objective has resulted. At present there is no well-developed or well-accepted single definition of QWL. There are, indeed, as many lists of QWL as there are social scientists and practicioners interested in exploring or defining the construct. Most lists contain wages, hours, working conditions, equity, social meaning, variety, social support, individual development, career opportunity, and a degree of control. There is general agreement that these ten or so aspects cover much of what employees say is high QWL on their present jobs. Some recent research into comprehensive employee-generated lists of QWL aspects reveals that measures developed by such a participative method are as much as 50% more powerful, aspredictors of employee attitudes, than standardized measures currently available (Levine, 1983a). Further, development of the participative approach permitted the use of multi-dimensional scaling analysis to further refine QWL "lists" generated by employees in order to identify additional QWL aspects. Such refined lists are shown to enhance the power of company and site specific QWL measures (Levine, et al, 1984). An additional benefit of this participative QWL measurement research is our increasing understanding of the connection between one's work and the company's product and purpose as a salient item for employees. Further, where all jobs in the work system are designed to be visibly central to the product and purpose there is a marked tendency for employees to include this "centrality" among the important determinants of their quality of working life (Gustavson & Taylor, 1982; Levine, 1983b). Finally (and despite the fact that little research has been done so far to confirm this) the combination of centrality of one's work to the company's product and purpose, together with a feeling of competence in doing that work, and the social or community relevance of the product seems to be a more potent predictor of high QWL in an effective organization than the simple summation of these three aspects would suggest.

STS and Quality of Working Life. Socio-technical systems approach to job and work design, unlike its industrial era predecessors, directly addresses the issues of purpose and product in organizations, and calls for identifying and controlling technical variances (cf. Taylor, 1978) at their source as a means of achieving quality increases and costs reduction. In so doing it requires that jobs be designed to support human cooperation and coordination in the control of those variances, and places the coordination functions at the lowest organization level. If the design approach is also participatory, employees involved in the design process will better understand their technical system, and the reasons why their organization is designed the way it is. This understanding of the big picture is developing an awareness of the organization as a living system, and of their jobs as interdependent and essential parts of it.

Employees (management and non-management alike) thus have an opportunity to experience higher QWL through: First, a sense of the importance or relevance of their product to the larger community, and of its distinctive competence; Second through the understanding of their place or direct role in creating the product; and Third through the opportunity to become competent in dealing with those activities most central to the effective creation of a product of importance and relevance to their customers.

COMPUTER-BASED INFORMATION SYSTEMS IN MANUFACTURING

The term "technological innovation" can mean many things. "High-tech" companies, in accepted usage, refers to industries in which a relatively high proportion of the average firm's revenues are spent on research and development--hence they are research intensive. Such industries include aerospace, pharmaceuticals, computer, and semi-conductors. Although technological innovation is clearly one result of R&D in high-tech companies, the engineering results of technological innovation (new computer based innovations in particular) are diffused throughout a much larger segment of American industry. In the United States, computers have been applied to manufacturing production since the early 1950's. At that time numerically-controlled (NC) machine tools were used to control metal cutting operations on large aircraft parts and employees were relegated to machine-tending activities such as loading and unloading parts.

Since that time many other computer applications have been developed in manufacturing which can affect the jobs of blue-collar employees. These newer applications include industrial robots, computer aided design and manufacturing (CAD/CAM), computerized inventory control, and parts tracking.

These separate computerized operations have been installed in a variety of manufacturing settings (some of them much more widely than others), and until recently they have not been combined in production applications. Examples of computerized manufacturing systems are the highly sophisticated parts and materials control systems called manufacturing resource planning systems (MRPS), and the integrated CAD/CAM-MRPS called "flexible manufacturing systems." In the U.S. these total systems are still rare, and their effects on blue-collar workers are largely unstudied. In effect, the "factory of the future" remains in the future. An apt summary recently heard is, "CAD is a fad, and CAM is a sham."

The effects of the separate computerized modules on the worker's job and autonomy at work are known, and they are not consistent with the values of human dignity and the development of human competence. Workers who remain today, after computerized modules are installed, are often still machine-tenders. The meager positive effects for such computer-tending workers in the U.S. today are merely the replacement of repetition with tedium.

A new model of technological diffusion is to recognize that we can use our new technologies to deal with that which we've never dealt with before, or to free us up to deal with it. Richard Byrne, Dean of the Annenberg School of Communication at the The University of Southern California calls this decision making in novel settings, "managing in the void". It follows that technology CAN help us manage in the void, but the secret is NOT to start with the technology. If we start with the technology, we're very likely to be stuck with merely a "horseless carriage" or a "factory without people." The horseless carriage is an illustration of doing old things

new ways when what we may want is to do something that we have not done before. When the old way was to produce a reliable product in great quantity, new demands for survival might include adapting appropriately and flexibly with a multitude of products to changes in the market. Unlike the Japanese, American automobile manufacturers have not yet embraced flexible manufacturing as a way of producing a multitude of rapidly changing models. Perhaps the Americans have not yet realized the impact of flexibility on organizational success and survival in the automative market. They apparantly see new technology merely as a way of replacing workers and substituting labor costs with technological ones. "Flexible manufacturing systems" may do a great job of helping a firm adapt, but the low U.S. diffusion rate for this innovation suggests that potential users see it merely as a costly "horseless carriage".

"Big Brother" and computers in blue-collar work. In this year of 1984 it is not inappropriate to consider the intrusion of technology into the worker's life. If we look at the potential negative effects (apart from unemployment) we find that workers are often carefully monitored by the computers they tend. This computerized supervision has not been the major thrust of the designers of these programs, but it is easily available, almost as a by-product. From the workers' point of view this can be seen as management and the machine playing "big brother." From a management perspective such automated surveillance is often seen as nothing more than an extension of past practices.

Traditional manufacturing in other countries (e.g., Japan and Sweden) is more heavily computerized than the U.S., per capita, and the production worker is more often in a position of controlling or managing the process, than in merely attending to it and being monitored by it. This control is due to the way that process is designed. The values and resources of employees are more often taken into consideration in this design abroad than at home.

North American experience with computer-based manufacturing is considerable in the new "high tech" areas of electronics and microcomputers. They often have rather specialized manufacturing technologies and use computers for portions (often fragmented) of those processes. These North American "high-tech" industries, despite their use of computers at the work place, are no more advanced than their traditional counterparts in their design of work or in the use of worker competence or potential. If they are to survive, these companies must use advanced technology-and use it wisely. The mobility of scientists, engineers, and manufacturing personnel makes maintenance of a high-tech firm's technical advantage difficult. If that mobility is caused by employee distress and frustation with the quality of their current working lives, in addition to the attraction of opportunities with other firms, survival of the firm itself becomes an issue.

Technological Innovation in "High-tech". Introduction of the microprocessor-the computer on a chip-has dramatically lowered the cost and expanded application of industrial automation such as robotics, NC machines and CAD/CAM. But within that significant event is an example of another type of technical effect on work and workers, not of automation as it is typically understood; but as the elimination of the need for conventional workplace structure and organization, because of a radical change in product technology. Fifteen years ago workers with soldering irons meticulously hand-assembled and wired electronic circuits containing separate electronics components such as transistors, condensors, and resistors onto metal frames; today, many fewer workers tend exotic computer-assisted

equipment to fabricate computers-on-chips in batches of up to 4,000 circuits at a time. It is as if the new fabrication facilities were automated in the conventional sense-many workers have been displaced or made redundant-but it is the product technology itself that has changed the production process, rather than merely the computer control of the process. Indeed, the semi-conductor fabrication process involves the use of computers for automatic control, but the basic worker activities of handling the silicon wafers often requires human intervention and override rather than mere monitoring of the machines.

The North American dilemma has been how to reconcile the industrial era assumptions of technological determinism with the post-industrial requirements for coping with unpredictable and turbulent environments (Davis and Taylor, 1976). Technological determinism leads to the conclusion that technology is the most important element and jobs, work, and organization must be subordinated to support it. Technological determinism assumes that there is "one best way", and that way is called for by the technology. Although the dilemma is not yet resolved, North American experience is accumulating to show that new forms of work organization, designed to address social and psychological requirements as well as technical ones, are better able to provide for the flexibility of organizational response which characterizes company success (Peters and Waterman, 1982). The American electronics industry has grown up literally since the period of the decline of effectiveness of Scientific Management principles. Because that industry started small and grew so quickly, the amount of concern for organization design at all has been small in relation to desire for technological innovation, and the pursuit of private fortunes. Thus the organizations we see in current U.S. electronics firms are inadvertant copies of the Scientific Management model of 1910-1950 industrial success--and of 1960-1980 decline. Although the capital investment in microelectronics technology has provided a marked improvement over the earlier products in cost and availability, the American microprocessor industry has not been able to compete favorably with the Japanese when both are using similiar production processes for similiar products.

SOCIO-TECHNICAL SYSTEMS AND HIGH-TECH MANUFACTURING

Socio-technical systems methods provide organization and job design techniques which provide workers in computer-based manufacturing settings with greater control over their work, and greater quality of working life through feelings of personal competence, a central place in the product stream, and social relevance of that product. Further, STS designs result in higher performance as well. Socio-technical designs have been successfully implemented in a variety of settings in North America and Western Europe. These designs are becoming increasingly visible, but they are not yet widely accepted. Manufacturing managers (especially in the U.S.) must first accept that employees' values must play a role with the values of the designers of the technology and with the values of the managers who adopt it.

The Zilog Experience. An illustrative case involves the use and effects of socio-technical design methods in microprocessor fabrication. It represents an excursion into organizational design, a new area for the industry, and it shows how effective both in speed of application, and permanance in effects socio-technical designs can be. Nowhere is this effect better demonstrated than in the Nampa, Idaho semiconductor plant of Zilog, Inc., a subsidiary of Exxon Enterprises, the producer of a wide variety of high performance microprocessor chips. The work-design process involved three steps. The first was putting the Nampa purpose, or "mission", into

words-which was to produce high-quality circuits at low social and economic cost. The second was to analyze, and perceptually "reframe," the technical process involved in producing good circuits. The third step involved designing a social organization (including the division of labor, the design of jobs, and the location of internal departmental boundaries) to match both the needs of people who would staff the organization, and to control the key technical aspects revealed in the technical analysis. The social organization guides the limits of authority, of standards for cooperation and of roles for coordination. It is based on a clearly articulated set of values and beliefs about people that all employees are trustworthy, that they can learn and grow, that they can accept responsibility for their product and that they can work together in harmony.

The design involved reorganizing the work away from narrow "operator's" jobs assigned to particular machines, to broader roles as "manufacturing techs" assigned in groups of people operating a number of machines, and responsible for an identifiable portion of the product. Training was changed to emphasise the important outcomes in the products which were necessary to create high quality, and employees in all departments were encouraged and rewarded to train and assist one another in the creation of high quality products. Zilog management entered this process fully committed to, and supportive of organizational design for organization purpose and human values. Responsibility for quality is driven to its lowest possible level. It is taken as a premise for this design, that people enjoy making decisions, taking on responsibility, and reaching a level of task ownership.

The first reaction of people who visit Nampa, or people in the industry who hear how the plant works usually say, "...sounds super! How can we possibly have lived without it for so long?" The other reaction to Nampa is completely different. "It can't possibly work, at least not in the long term. It's just too unstructured."

For the five years of its existance, the Nampa plant design has worked very well indeed. Here are some examples. Gustavson & Taylor, (1984) report the process and the early results in greater detail. Since 1979 Nampa has a less than six per cent turnover. The typical rate for fab plants for the same period averaged between 40 to 60 per cent. This low attrition rate translates into higher performance and greater efficiency as well as dollar savings. Plant costs began going down almost immediately following start-up. The investment cost is largely dependent on how quickly a plant gets up to standard production. Assuming a constant monthly expense, Zilog had an expectation of just how long getting up to standard might take. That time was cut by 50 per cent. Therefore, they were able to cut the start-up investment by a like amount. The plant has had a dramatic increase in product quality yield compared to company experience in their "Silicon Valley" facility, and and compared with reports of yields in other firms. Yields at Nampa exceed those of comparable facilities by more than 25 per cent. They thus perform well above the industry average. Their success, however, is not only measured in yields-the team approach has reduced the amount of rework, and therefore also the cost of labor. Finally, the employees registered an extremely high self-rating of quality of working life.

CONCLUSION

This highly successful case provides evidence that technology can be applied to appropriate, and conscious organizational purposes, and human values. This sociotechnical redesign, and others like it, are manifestations of technological choice, and they do form an expression of an organization's purpose. The other technological choices available are to apply a new technology for old tasks, for example close supervision (an expensive, if not inappropriate decision), or to avoid technological innovation. These choices, too, reveal a world view.

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